Compact Optical Imager for Real-time, 3-D Range, Intensity and Fluorescence Mapping of the Ocean Floor

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LONG-TERM GOALS

Our research is directed toward development of an automated sensor for capturing 3-D images of man-made and natural objects in aqueous environments. We strive to construct a compact instrument capable of real-time imaging and classification of imaged objects using state-of-the-art optoelectronic technology. We expect that this work will have relevance to the in-water investigation and surveillance needs of branches of the U.S. Military, U.S. Intelligence agencies, as well as state and local law-enforcement agencies.

OBJECTIVES

Our Real-time Ocean Bottom Optical Topographer (ROBOT) prototype demonstrated the feasibility of our technical approach. The objectives of the current work include development of an embedded real-time image-processing system and further development of optical models describing ambient light conditions and laser-beam attenuation to determine operating conditions suitable for ROBOT.

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APPROACH

The operating principle behind our optical 3-D imager is triangulation and has proven to be effective for generating accurate 3-D images (Kaltenbacher et al., 2000). We will utilize digital signal processor (DSP) integrated circuits to implement our embedded version of this instrument. This approach facilitates a compact low-power design without the overhead of standard computer hardware and operating systems. In the current system, the major components are packaged in separate pressure vessels. A single (albeit more complex) vessel will be used to repackage the system to fit smaller AUVs. By utilizing environmental and vehicle data we endeavor to construct a robust sensor system with predictable operational characteristics. Monte Carlo analyses will be used to quantify scattering effects in the water to predict sensor performance in varied environments. Global positioning data from GPS receivers will be used concurrently with acoustic local tracking to geodetically reference the sensor's position enabling precise target location and image mosaics information from individual scans.

Key personnel: E. Kaltenbacher (Lead Engineer), J. Patten (Software Engineer), D. Costello (Ocean Optics Researcher), K. Carder (Lead Scientist) and Center for Ocean Technology (COT) Engineers and Technicians.

WORK COMPLETED

As our funding for this year became active in early August, our project is just beginning. We have, however, completed the following items. We have completed the fabrication, testing and debugging of the DSP-based image processor started under previous year's funding. These electronics constitute a major developmental effort with significant advantages over the prototype system. First, the power consumption is roughly 25% of the prior version. As vehicles and payloads become smaller, this will enable the use of smaller batteries without sacrificing mission run times. The physical size of these electronics is also considerably smaller, providing the means to fit the sensor in the new smaller AUVs.

We have identified potential sources of hardware from which to base the design of the custom camera. Burle manufactures a compact self-contained intensifier with the requisite resolution for our application. A CMOS image sensor made by Kodak offers the flexibility for frame rates and image size needed for this project. We are currently finalizing the research into these items and expect to make purchase in the next few weeks.

Work over the remainder of the project is summarized below.

1. Expand current DSP electronics with data storage and peripheral interfaces.

2. Develop highly-sensitive and flexible camera.

3. Develop custom line generating and imaging optics.

4. Package the system for deployments in compact AUVs and ROVs.

5. Expand and refine optical models describing ambient light fields.

RESULTS

The first version of the DSP-based, image-processing electronics is shown in Figure 1. The circuit board is shown temporarily mounted in a plastic case for protection during testing and development of additional features. The initial version of the DSP-board operates at 700 Mhz, offering several hundred operations/pixel at 30 frames/sec.

Figure 1: A photo of the circuit board mounted temporarily in a plastic case for protection. [The circuit board measures roughly 5x7 inches and is mounted in a plastic case measuring 6x8x 4 inches. The circuit board is densely populated with several hundred surface mount components].

IMPACT/APPLICATIONS

The ROBOT instrument presented in this work can be used to accurately provide 3-D images in a variety of conditions. Applications of this sensor include object detection (e.g. mines, coral), contour mapping (e.g. sand waves), crash site investigations, and port security (hull inspection, sea wall mapping). ROBOT data can also be used in shallow coastal waters to ground-truth remote sensing data (Carder et al. 2003). Our instrument is simple, portable, relatively inexpensive and suitable for use on a wide variety of platforms.

TRANSITIONS

The technology development in this work can be extended to analysis of terrestrial areas considered too dangerous for human investigation. This instrument can analyze debris and other aspects of crime scenes or other hazardous areas. Local law enforcement agencies have expressed interest in utilizing ROBOT for in-water forensics. ROBOT forms the basis for a project with the U.S. Coast Guard and Navy utilizing ROBOT for port security by scanning ships' hulls and seawalls.

RELATED PROJECTS

Development efforts on navigation and AUV control were funded under ONR #N00014-02-1-0267 "Autonomous Ship Detection System". Studies in modeling and measuring seawater optical properties were funded by ONR #N000140-02-1-0211 "Optical Variability and Bottom Classification in Turbid Waters: Phase II" and #N00014-03-1-0177 "Distribution of our CoBOP Results: IOPs and Albedo Spectra for Incorporation into Radiative Transfer Models." Ambient light condition modeling was funding by ONR #N00014-03-1-0625 "A Hybrid Modular Optical Model To Predict 2-D and 3-D Environments in Ports and Beneath Ship Hulls for AUV Sensor-Performance Optimization in MCM Activities."

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